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### WATER CONTROL IN CENTRAL AND SOUTHERN FLORIDA

by Harold A. Scott, M. ASCE

### IRRIGATION AND DRAINAGE DIVISION

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## WATER CONTROL IN CENTRAL AND SOUTHERN FLORIDA

Harold A. Scott,<sup>1</sup> M. ASCE

### SYNOPSIS

This paper describes the historical efforts made to provide drainage and water control to central and southern Florida. Distribution and utilization of water in the Comprehensive Plan for flood control and multiple purposes are described. The need for a secondary water control plan is emphasized.

The area discussed in this paper lies generally south of a line extending from Lake Harney in the St. Johns River Basin and east of the ridge that divides the waters which flow into the Atlantic and those which reach the Gulf of Mexico, as shown on plate 1. The water-control problems of the area are quite common although there is some difference in topography and soil. The area consists of about 15,000 square miles of groveland, pastures, rich agricultural lands, lakes, and marsh lands. Elevations range from about 7 feet<sup>2</sup> in the vicinity of Miami and 15 feet around Lake Okeechobee to 80 feet in the headwaters of the Kissimmee River Basin. However, the slope of the lands of much of the area is extremely flat and natural water courses are not common. Other than the St. Johns and Kissimmee Rivers, Fisheating Creek, and a few minor streams, most of the water control is managed by man-made canals and drainage districts. Soils in the area vary from sand to peat with some marl. The areas with higher elevations in the St. Johns and Kissimmee River Basins consist of sand with a small amount of organic material mixed in the upper 6 to 12 inches. In the low areas and marshes, deposits of peat ranging up to several feet in thickness are to be found. The Everglades is covered with a layer of peat ranging up to about 15 feet at Lake Okeechobee and gradually diminishing to zero at the edges. From the St. Lucie Canal south to the tip of Florida, a low ridge of sand, limestone, and marl forms a divide between the Everglades and drainage to the ocean. In the vicinity of Miami the area is underlain by porous limerock which makes the problem of water control quite difficult.

Mean annual rainfall is about 58 inches at Miami, 70 inches southerly of West Palm Beach, and 51 inches at Kissimmee. The mean values are rather deceiving when studied for water-control purposes. For instance rainfall of 10 inches during the summer months is quite common. Furthermore, 70 percent of the rainfall occurs during May to October, inclusive, which is considered the wet season. During the wet season,

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2. All stages and elevations throughout this paper refer to mean sea level datum.

rainfall averages about 7 inches a month whereas the average is only 2 to 3 inches for the remaining 6 dry months.

Mean annual temperatures vary from 75° Fahrenheit at Miami to 72° at Kissimmee. The water areas provided by the lakes and marshes, and the proximity of the Atlantic Ocean and the Gulf of Mexico temper the climate, and extreme ranges are not great or frequent. Highest summer temperatures seldom exceed 100° and winter temperatures as low as 20° have been experienced. The relative humidity is generally high throughout the area.

Evaporation and transpiration are very high throughout the area and particularly where large water surfaces are exposed. Estimates indicate an excess of average annual rainfall over evaporation of only about 9 inches around Lake Okeechobee and about 12 inches in the Everglades. Therefore, the effect of evaporation is a primary factor in water control.

Numerous floods have covered the central and southern Florida area. However, the 1947 flood outstripped them all. The entire area was under water except for a few drainage districts protected by dikes and a few high areas here and there in the 15,000 square miles. The water was not able to drain to the ocean, being hindered by the low coastal ridge between the Everglades and the coast. The storage areas that exist are shallow and have a most limited capacity. In 1948 a similar flood of lesser proportions covered the area, and once again only those areas protected by dikes or having higher elevation were saved from flood damage.

The area has suffered from many severe droughts. The most notable of recent years occurred in 1942-43, and again in 1945. It cannot be said that there was no water since there were many lakes with an abundant supply, but there was no distribution system with which to pass that water to the areas of greatest need.

In view of the severe floods and droughts, the uneven distribution of rainfall, and the generally flat topography, the need for a sound water-control program becomes a paramount problem.

In order to better understand the value and need for a plan, it appears desirable to review briefly the history of drainage and water control in central and southern Florida. The first report on the Everglades was made in 1847-48 by Buckingham Smith, an agent appointed by the Secretary of the Treasury. In 1881 the Trustees of the Internal Improvement Fund contracted with Hamilton Disston and Associates for the sale of 4 million acres of land. Disston concentrated his efforts in the Caloosahatchee and Kissimmee River Basins. The Everglades, some 2,862,080 acres of land, was conveyed to the State of Florida in 1903 under the Swamp and Overflow Land Grant Act of September 28, 1950. That area has presented one of the most difficult engineering problems to solve.

The actual start of the State's drainage plan for the Everglades began in 1905 when the legislature adopted a drainage law providing for the establishment of boundaries of an Everglades Drainage District. Actual construction was begun in 1906. By 1912, eight dredges were at work on canal excavation in the Everglades. In 1913 the Everglades Drainage District was created. The Board of Commissioners of the Everglades District and the Trustees of the Internal Improvement Fund requested a

report be made by the Florida Everglades Engineering Commission. The report contained recommendations for approximate locations of canal routes and estimates of cost for reclaiming the Everglades. By that time the North New River, South New River, and Miami Canals had been excavated; Cypress Creek, Snake Creek, Snapper Creek, and Hillsboro Canals were under construction; a contract had been let for the West Palm Beach Canal. The plan of the Commission recommended additional canals as shown on plate 2. That system of canals was designed to drain the area by gravity with no provision for pumping. Also, no provision was made for storage other than Lake Okeechobee. Since the Everglades was predominantly swamp and there appeared to be an abundant supply of water, the need for irrigation to any large extent was not too seriously considered.

In 1927 the Everglades Engineering Board of Review prepared a report which proposed a system of arterial drainage canals as shown on plate 3. The plan, therein, substantially reduced the scope of drainage of the Everglades. However, the plan had one important advantage over that of 1913. The canals designated "B", "C", "E", "F", "J", "L", and "Q" followed the most direct alignment to the Atlantic Ocean. Consequently, they would have provided more positive drainage had their capacities been of sufficient magnitude to serve their tributary areas. However, little was done with that plan since the Everglades Drainage District defaulted on its bond payments on January 1, 1931, and practically all construction came to a standstill. In 1931 the water-control facilities were generally as shown on plate 4. During the next decade the works of the District deteriorated; canals filled with hyacinths, the locks fell into disuse, and the entire project became ineffective. Damage was sustained from either too much water or no water.

After the 1926 and 1928 hurricanes, the local residents made numerous requests of the Federal Government for assistance. As a result of those requests, the Caloosahatchee-Lake Okeechobee Drainage Area Project was authorized. That project consisted of 75 miles of levees around the lake, hurricane gate structures, locks on St. Lucie and Caloosahatchee Canals, and enlargement of those two canals. While those works helped the water-control problem of Lake Okeechobee, there was much to be desired in the "Glades." Troubles with water control continued, and new requests were directed to the Federal Government during the 1940's.

While the above effort was directed toward reclaiming the Everglades, other interests were equally as industrious in digging canals, building dikes, and creating drainage districts in the Kissimmee and upper St. Johns River Basins. Most notable are the numerous drainage districts astride the eastern divide between the upper St. Johns and Indian River Basins from the vicinity of Stuart to Rockledge. An active program was also carried on in joining the lakes by canalization in the headwaters of the Kissimmee River Basin.

By 1947 the Corps of Engineers had received 13 authorizations for reports in the central and southern Florida area covering flood control, navigation, and allied purposes. After recognizing the great need for a Comprehensive Plan for the area, work was started at an accelerated

schedule. However, before the report could be completed, the area was subjected to possibly the worst flood of record. The report, submitting a plan for major water-control works, was completed in December 1947, and about one-third of the work proposed therein was authorized by the Congress on June 30, 1948. The primary concern of the authorized portion of the plan was to provide a line of levees from Lake Okeechobee generally southward to the vicinity of Homestead, between the Everglades and the developed coastal area, and encircling the developed agricultural area.

Examination of the Comprehensive Plan (see plate 1) shows that a primary framework of water control has been developed. The structures are designed to remove water during flood periods with a minimum of damage and to protect ground-water supplies during droughts. The plan proposed improvements in the four more or less natural drainage basins that have such closely related water-control problems, namely, St. Johns, Kissimmee, Lake Okeechobee-Everglades, and the east coast from St. Lucie Canal south to the southern boundary of Dade County.

Overdrainage of St. Johns marsh area would seriously affect water supplies of the area. Therefore, the plan proposed to maintain those marsh areas at their present limits by providing levees at the northerly outlets of Lake Poinsett and Lake Washington; and by providing canals from those two lakes and Lake Wilmington to Indian River for the discharge of excess floodwaters, thereby reducing the amount and duration of flooding now experienced by the adjoining lands. The Belcher, Diversion, and St. Lucie-Martin County line canals would be developed and provided with water-control structures.

In Kissimmee River Basin, the canals between the headwater lakes would be improved and provided with water-control structures. That would include improvement of Kissimmee River between Lakes Kissimmee and Okeechobee. Canals and control structures would be provided for Lake Istokpoga and the area south to Lake Okeechobee.

In the Lake Okeechobee-Everglades area the plan proposed improving St. Lucie Canal and Caloosahatchee River to better control the lake; to raise the levees to provide greater protection; and to increase storage in the lake for beneficial purposes. Levees would be provided around about 1,000 square miles of rich agricultural land immediately south of the lake. That work is in progress with levee 8 completed and levees 1 and 7 under construction. One of the greatest differences between the Comprehensive Plan and any other is the provision of large pump stations to control water levels in the entire 1,000-square-mile area. Another great difference was the setting aside of about 1,400 square miles of the Everglades for water storage and conservation purposes. Those lands were recognized as not being suitable for long-term agriculture.

The east coast area would secure water control through improvement of existing canals capable of carrying storm run-off rapidly to the ocean. Water-control structures would be provided near the lower ends of the canals to control ground water and to retard the salt water flow upstream.

Since the authorized part of the comprehensive project lies in the Everglades and east coast areas, the problems of water control in those areas have received more study.



To meet the needs of the region and to obtain optimum use of the available water, it is necessary to store large quantities when excess water is available and to hold wasteful discharge to a minimum. Maintenance of a water supply in Lake Okeechobee and in the conservation areas would provide the following benefits:

- a. Water supply for agricultural areas.
- b. Improved ground-water control.
- c. Improvement and replenishment of east coast well fields and streams for municipal water supply.
- d. Salinity control for east coast areas.
- e. Recreational facilities on Lake Okeechobee and related waterways.
- f. Increased navigation depths in Lake Okeechobee and related waterways.
- g. Conservation of peat and muck lands of the agricultural area.
- h. Conditions favorable for propagation of fish and wildlife in Lake Okeechobee, the conservation areas, and Everglades National Park.

A study of the use and distribution of available water involves a knowledge of the optimum and normal requirements of the areas for the needs listed above; the present and ultimate demands of the areas affected; the total water supply available; and the amount of available water that can be distributed to satisfy the entire or partial needs of those areas.

The principal region that would benefit from, or be affected by, the sources and quantity of water made available by construction of project impoundment facilities is the Everglades area and contiguous east coast. That region averages about 40 miles in width, extends part of the way around the eastern and western shores of Lake Okeechobee, and reaches southward about 100 miles from the lake to the southern tip of Florida. It includes the entire lower east coast of Florida—the narrow coastal ridge where West Palm Beach, Fort Lauderdale, Miami, and many smaller communities are located. The major water-demand areas are:

- a. Lake Okeechobee agricultural area.
- b. Lake Worth agricultural area and adjacent east coast areas.
- c. Davie and Plantation agricultural areas and adjacent east coast areas.
- d. Davie and Miami agricultural areas and adjacent east coast areas.
- e. Everglades National Park.

The sources of water supply for those areas, the resulting benefits, and other pertinent data are given in table 4 on the following page.

The available water storage in Lake Okeechobee for the agricultural area would be the volume between the maximum conservation pool level and the lowest lake stage acceptable to local agricultural and navigation interests. Local agricultural interests would prefer that the minimum lake stage be not lower than about 13 feet; however, under natural conditions, the lake has fallen below 13 feet 16 times in the 38 years of record. The maximum acceptable conservation pool elevation depends on the stage at which seepage damage to highly developed lands on the

Table 4

## SOURCE OF WATER SUPPLY AND AREA OF DEMAND

Area of demand	Area (sq. mi.)	Area of supply	Area (sq. mi.)	Benefits
Lake Okeechobee	730	Kissimmee River Basin*	4,812	Navigation, recreation, fish and wildlife.
Agricultural area	1,130**	Lake Okeechobee	730	Water for agricultural use; conservation of peat and muck lands.
Conservation area:				
No. 1-----	216	Lake Okeechobee and		Fish and wildlife.
No. 2-----	204	agricultural area		
No. 3-----	924		1,748	
	1,344			
Lake Worth agricultural area	340	Conservation area No. 1	216	Water for agricultural and urban use.
Davie and Plantation agricultural areas	85	Conservation area No. 2	204	Water for agricultural and urban use.
Davie and Miami agricultural areas	220	Conservation area No. 3	924	Water for agricultural and urban use.
East coast area	-	Conservation areas Nos. 1, 2, and 3	1,344	Water supply, salinity control.
Everglades National Park	1,240	Conservation area No. 3, adjacent area run-off	-	Fish and wildlife, birdlife, vegetation.

NOTES: \* Including drainage areas of numerous streams around the northeast and lake shores.

\*\* 112 square miles drain to Caloosahatchee River.



lake margins would be great enough to require appreciable remedial measures. Attempts to maintain conservation pool stages in excess of that would necessitate establishing a buffer strip adjacent to the landward toe of the lake levees from the vicinity of Port Mayaca to Moore Haven, and constructing a ditch to collect seepage water and convey it to the main canals of the agricultural area. Since the required strip would include highly developed agricultural lands and would require relocation of highways, bridges, and other structures, the expenses would be considerable. The results of several routing studies made to determine the amount of storage that could be economically provided for agricultural use, assuming maximum conservation pool elevation at 13, 14, 15, and 16.4 feet, are shown in table 5.

Table 5

ROUTING STUDIES FOR AGRICULTURAL-USE STORAGE  
ULTIMATE DEVELOPMENT OF THE AREA

Upper limit, cons. pool (ft.)	Minimum lake stage reached (ft.)	Times lake below elev. 10.56 ft.	Months lake below elev. 10.56 ft.	Storage capacity avail. for agr. use (acre-ft.)	Agr. demands not satisfied (acre-ft.)	(months)
16.4	10.0	1	4	2,440,000	178,000	2
15.0	9.9	5	21	1,800,000	1,038,000	14
14.0	9.4	7	41	1,350,000	2,325,000	18
13.0	9.2	17	79	925,000	4,553,000	39

With the upper limit of the conservation pool at 16.4 feet, the volume of agricultural-use storage, about 2,440,000 acre-feet, would have been adequate to meet all requirements arising from the ultimate development of the area in the 38 years of record except in 1922 when the lake would have been below elevation 10.5 feet for about 4 months. Under the same conditions of storage, practically all of the capacity would have been required to satisfy requirements to the two next driest years. About 400,000 acre-feet of additional storage would have been required to fully satisfy the agricultural requirements in 1922 assuming ultimate development without dropping below elevation 10.5 feet. That amount could not be stored without raising the lake to above elevation 17 feet. However, by assuming water stored to an elevation above 17 feet, the lower limit would have been higher than 10.5 feet in 1922. Increased benefits that would result from provision for the additional storage at this time would be realized so infrequently as to become relatively insignificant.

Water control in the agricultural area south of Lake Okeechobee is dependent on pumping. The capacities chosen for the pump stations and agricultural canals are those required for removal of three-fourths inch of rainfall a day from the drainage area served. That capacity

was selected after investigations of rainfall, flood duration, and crop losses. From a long-range basis all water possible should be stored and the remainder discharged through the Everglades National Park to obtain the maximum benefits for conservation purposes.

Similarly, routings were made for the three conservation areas. Those routings established pool elevations of 17 and 15.9 feet to provide the maximum water-control benefits for conservation areas Nos. 1 and 2 respectively. In conservation area No. 3 the surface storage was found to be limited not by the capacity, but by the available supply. Most of the demand would come from ground water.

The water requirements of the various component urban areas of the region were developed. The major requirement of the region is supplemental water to permit the orderly development of agricultural land lying south and east of Lake Okeechobee and east of the conservation areas, although municipal water demands during the life of the project may require water to supplement existing supplies. The provision of an adequate water supply to meet those two fundamental requirements for the development of the area would make the best use of available water. Such provision would also result in supplemental benefits in the maintenance of ground-water levels sufficiently high to conserve peat and muck soils, and would materially assist in restricting the intrusion of salt water to coastal lands. It is also apparent that the creation of additional water to serve useful purposes would provide attendant benefits to fish and wildlife resources; and would increase the recreational facilities of the region. Table 12 summarizes the present water consumption and the consumption for the year 2000 for agricultural and municipal water supply in the major subdivisions of the region of demand.

Municipal water supply for the coastal urban centers would be dependent to a degree on releases of water from the conservation areas; however, the major part of the supply would be obtained from ground-water sources which would be maintained by rainfall, seepage of water from nearby farm areas, and seepage from the conservation pools and from several lakes. Since present water supply for the area would be adequate for ultimate development during the greater part of the time, it has been considered that any additional water required during severe droughts would be available as increased seepage from the conservation and agricultural areas.

Routings were made to determine the flow distribution of a design flood, an average water year, and a drought year. (See plates 5, 6, and 7.) The distribution of the design flood, plate 5, can be considered similar to that which would occur during any flood of considerable magnitude. The larger the flood, the more water which will have to be discharged through St. Lucie and Caloosahatchee Canals and into Everglades National Park. The distribution of the average year, plate 6, is representative of long-term utilization and was developed from 12 years of record. During the average year, evaporation accounts for the greatest quantity of water. Only a small amount is discharged for non-productive uses. Such discharge indicates that only a small increase in land area can be supplied with water during normal times. The

Table 12

## PRESENT AND PROSPECTIVE WATER CONSUMPTION FOR PRINCIPAL AREAS OF DEMAND

Region of demand	Area (sq.mi.)	Water usage	Development—year 1950			Development—year 2000		
			Acreage under water control	Population	Water consumption (ac. - ft.)	Acreage	Population	Maximum water demand (ac. - ft.)
Lake Okeechobee agri. area	1,130	Agriculture	127,000	-	155,000	723,200	-	883,000
Lake Worth area	340	Agriculture Municipal	36,000	-	20,000	150,000	-	147,000
			-	139,000	22,000	-	417,000	71,000
Davie and Plantation areas	85	Agriculture Municipal	17,000	-	7,400	54,000	-	56,300
			-	*	*	-	*	*
Davie and Miami areas	220	Agriculture Municipal	46,000	-	23,700	123,000	-	134,000
			-	535,000	60,000	-	1,605,000	269,000

NOTE: \* Included in Lake Worth area.

drought year, plate 7, shows how critical the water supply will be. No water is discharged for nonproductive uses and only a very small amount is available.

On plate 8 the utilization of water is shown in percent of the total available water supply. During the average year the water that is discharged through the West Palm Beach and Hillsboro Canals is available in conservation areas Nos. 1 and 2.

The significant point in these distribution routings is to indicate the amount of water available to the area. However, in addition to the area mentioned above for which water would be available during an average year, there are thousands of acres of other lands in the adjacent area—that is, Hendry, Glades, Okeechobee, Martin, and Palm Beach Counties—which must have irrigation water for complete development. Owners of those lands have already initiated requests for supply from Lake Okeechobee. It is apparent that insufficient water is available to supply all of those lands in addition to the agricultural area and the east coast area. Some plan must be developed to determine which lands will be supplied from Lake Okeechobee.

Federal law does not permit the Corps of Engineers to develop a complete distribution plan for water utilization or a secondary plan down to the level of lateral canal distribution or collection systems, and local storage areas. That development, which would fit into the Comprehensive Plan, is a local responsibility. The Central and Southern Florida Flood Control District, a State agency representing local interests in water-control matters, has adopted a secondary distribution and drainage plan for the Everglades agricultural area. That secondary plan includes the small drainage districts and landowner's works in addition to canals and controls that would permit the maximum benefits to be realized from the Comprehensive Plan or primary plan. A portion of the secondary plan for the West Palm Beach Canal is shown on plate 9. It can be seen that provision for water control has been made in the most remote areas.

In order to realize the maximum development throughout the central and southern Florida area, it is imperative that a secondary water-control plan be prepared for the entire 15,000 square miles. Such a plan will develop an understanding by local residents of the inadequacy of the water supply in the area; and a cataloging of the water supply, land use, and storage possibilities. The plan will result in classification of lands which are susceptible to complete water control and those which would have only limited facilities. The Central and Southern Florida Flood Control District is engaged in cooperating with the individual counties of the area to work up a secondary plan. At present the people are becoming more water-control conscious than ever before in the history of Florida.

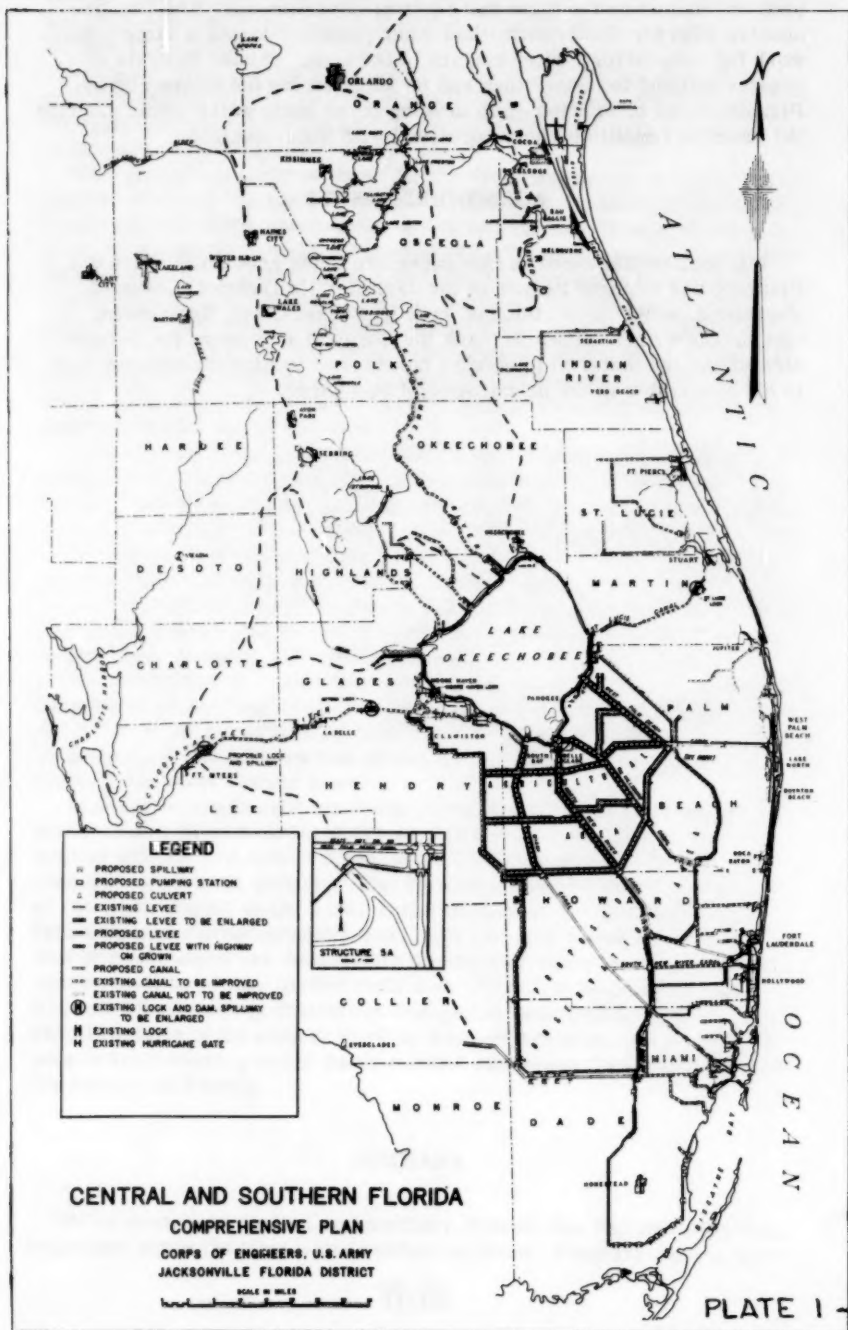
#### SUMMARY

Water control in central and southern Florida has had intensive consideration since the first white settlers arrived. Primary efforts have

been carried on by the State and Federal Governments. The Comprehensive Plan for flood control and other purposes forms a basic framework for satisfactory water control in the area. Studies indicate a greater demand for water than can be supplied for the entire region. Planning must be carried on to develop those lands which would produce the greatest benefits by being provided with water control.

#### ACKNOWLEDGMENTS

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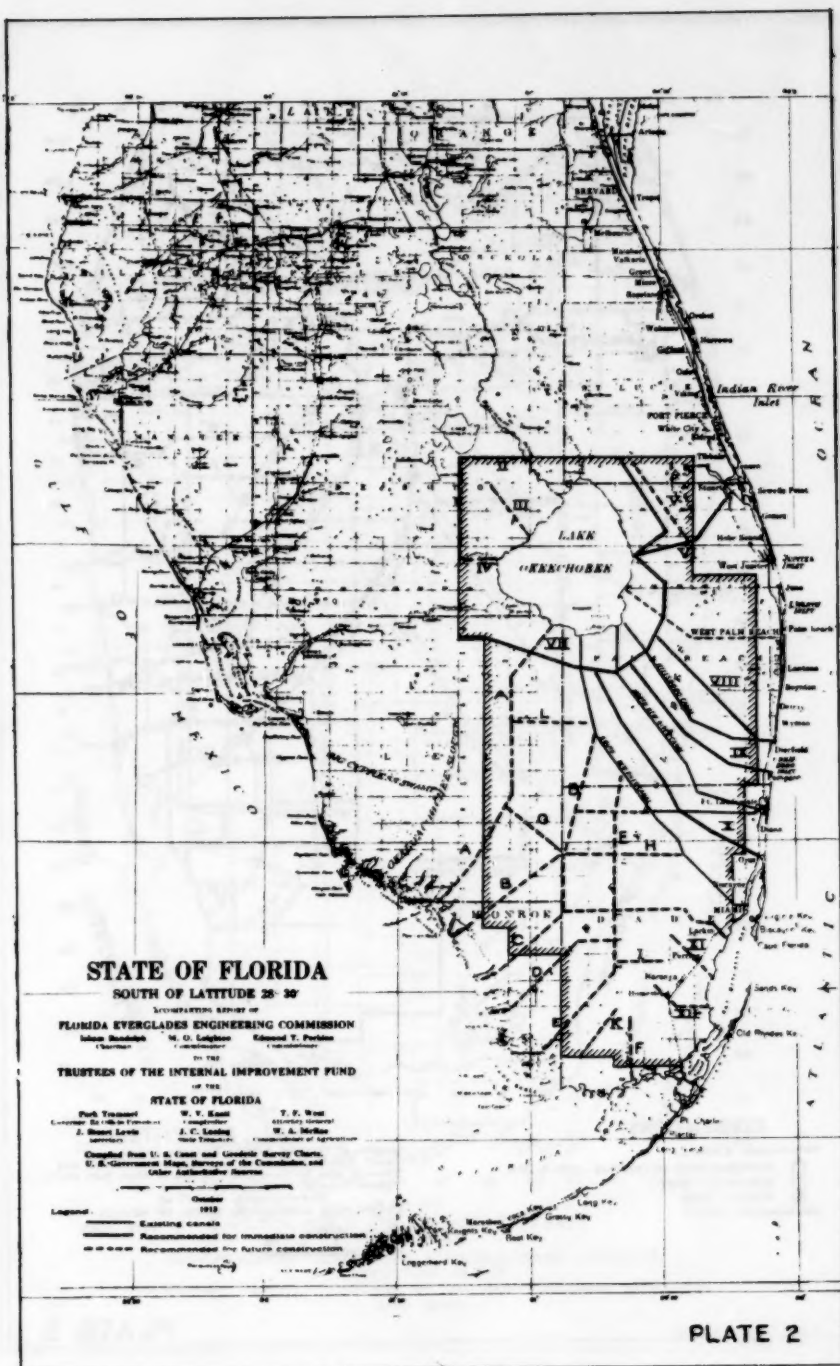
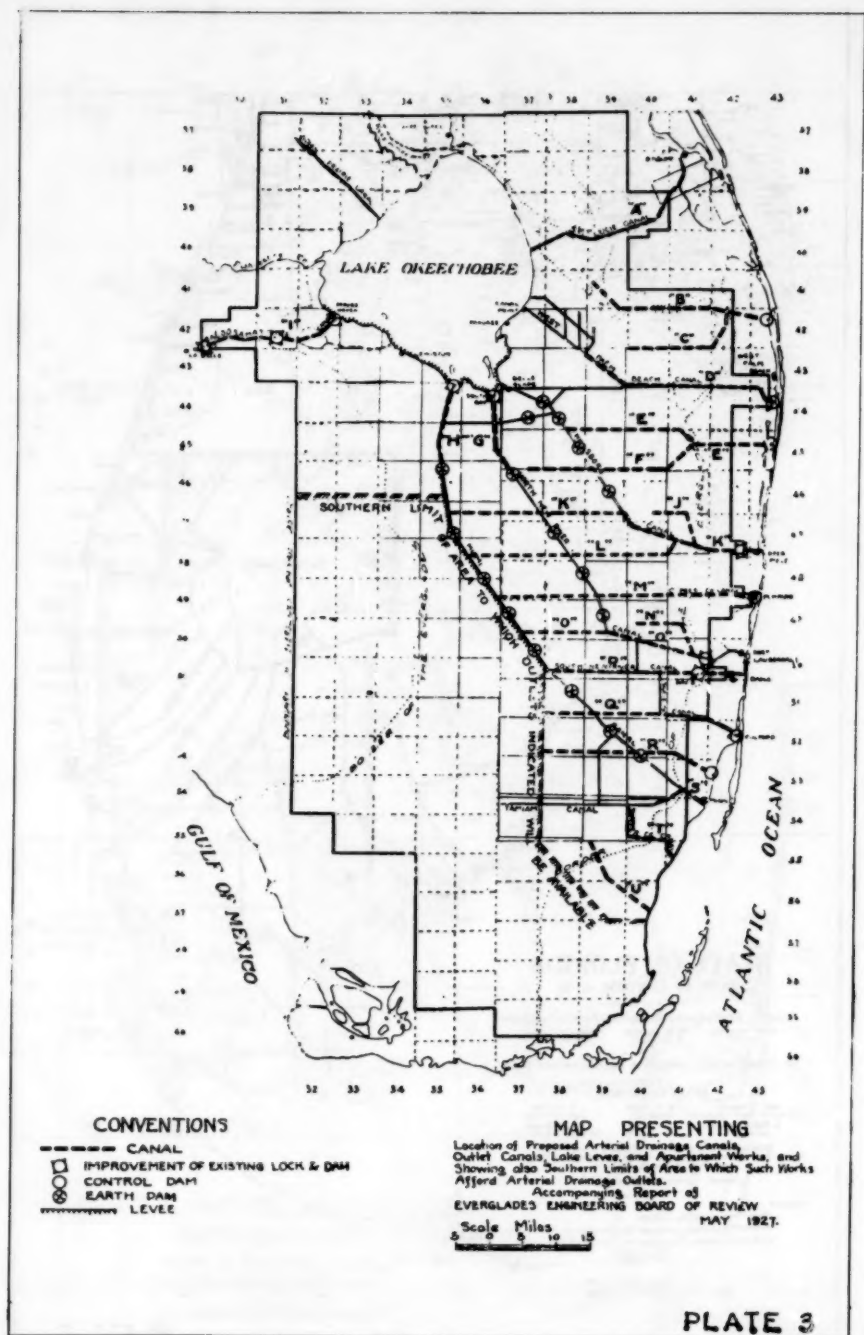
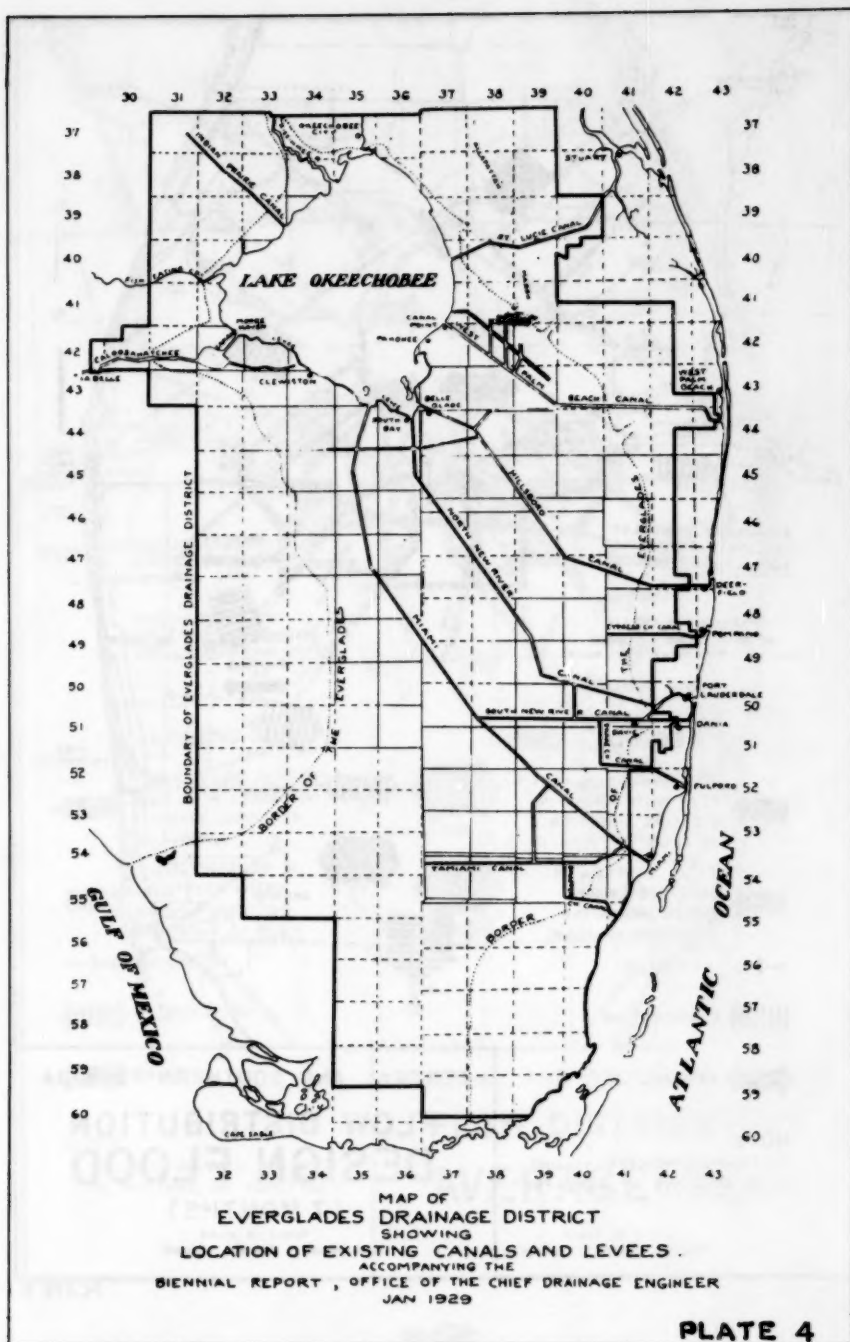


PLATE 2





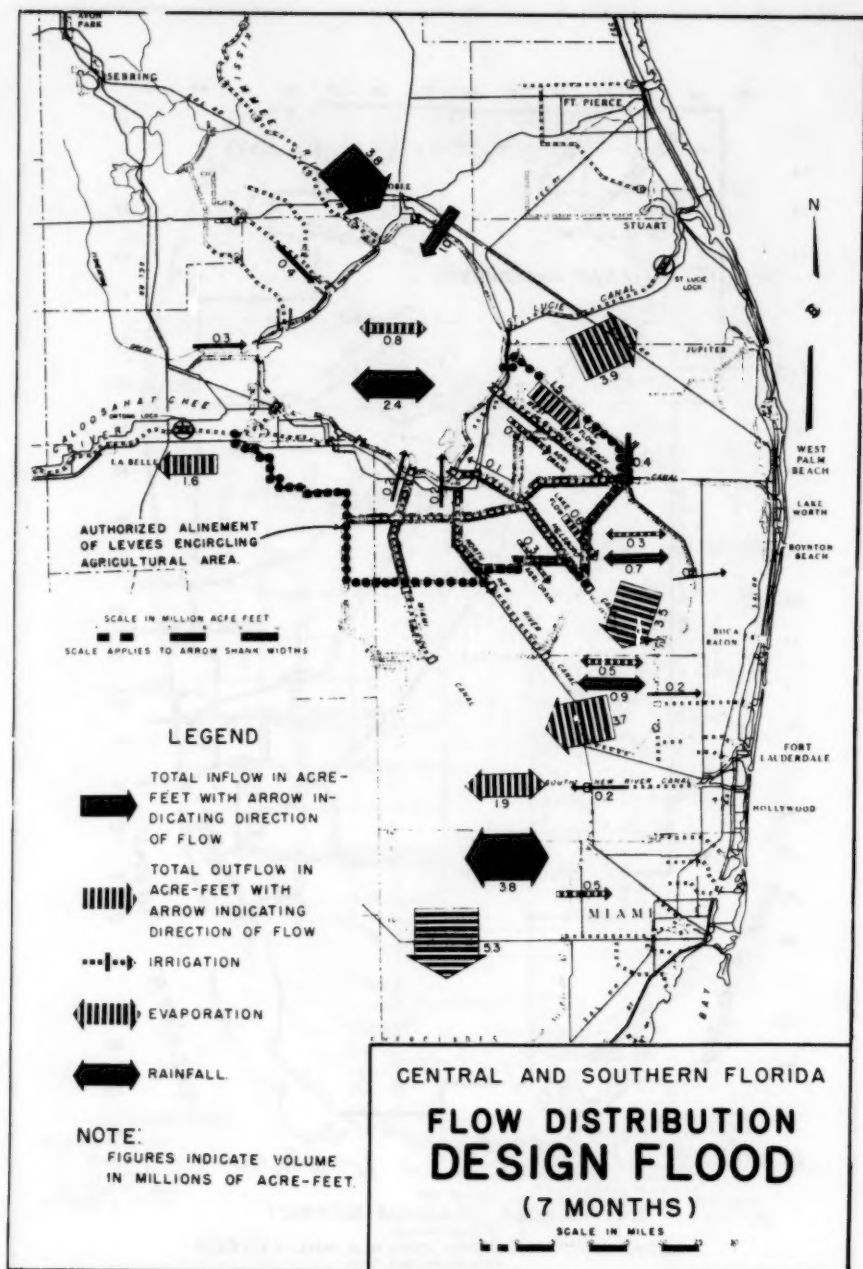


PLATE 3

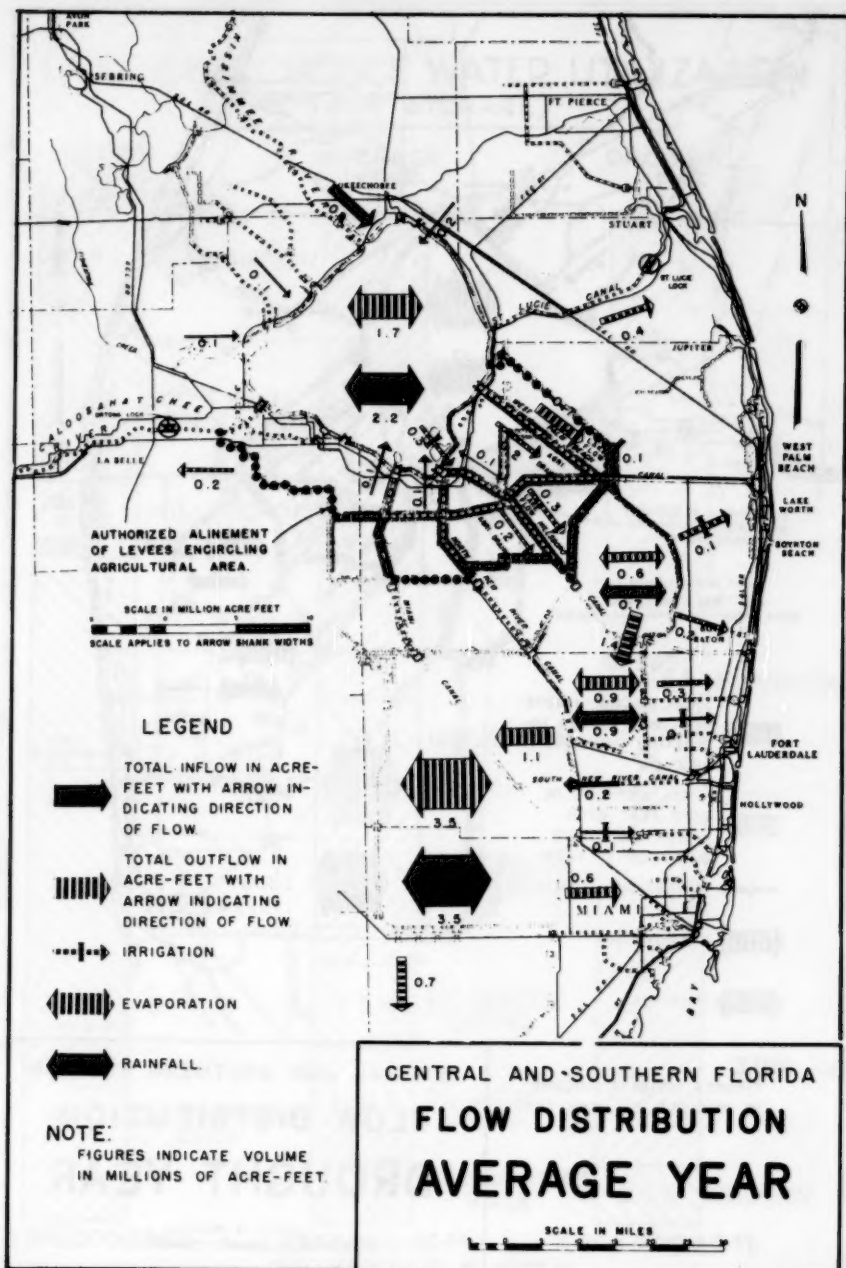


PLATE 6

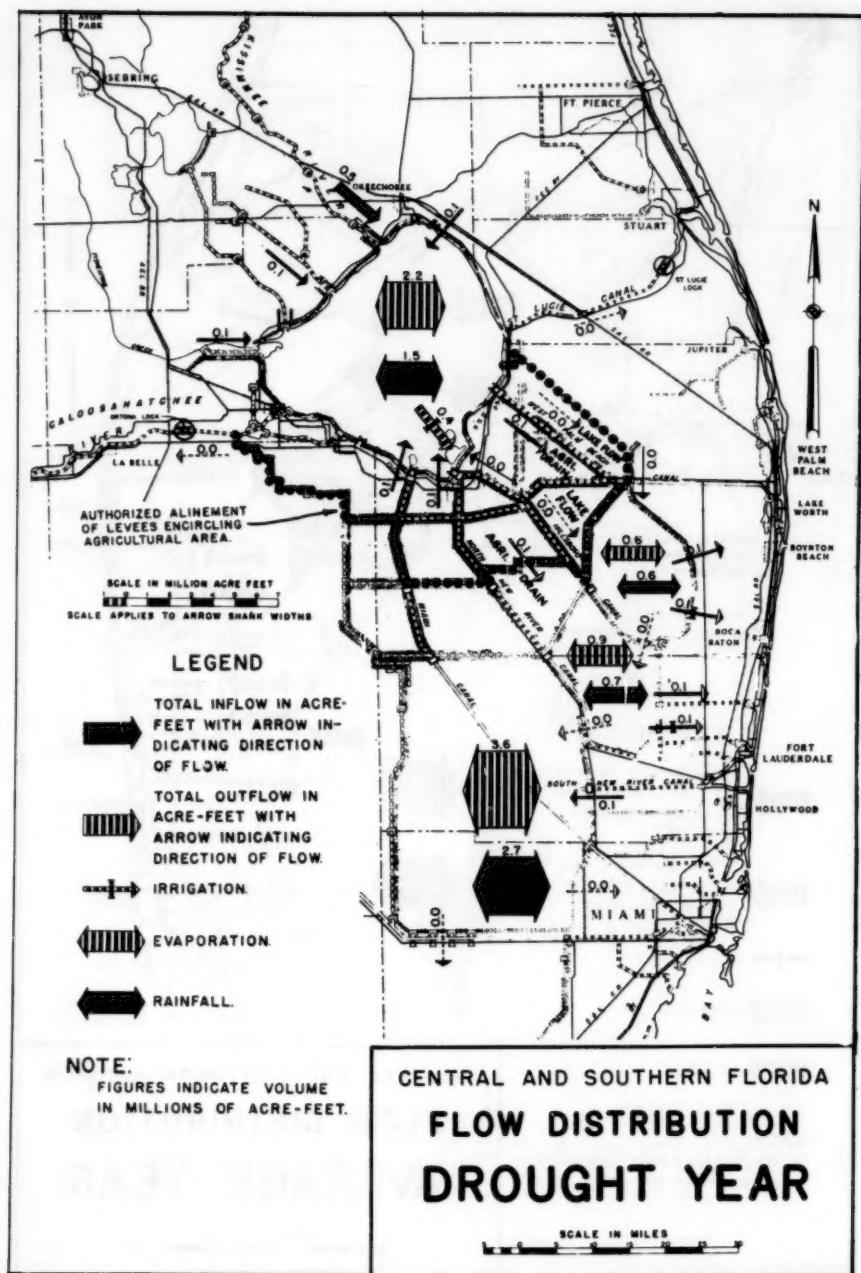


PLATE 7



# LAKE OKEECHOBEE WATER UTILIZATION (WITHOUT STORAGE)

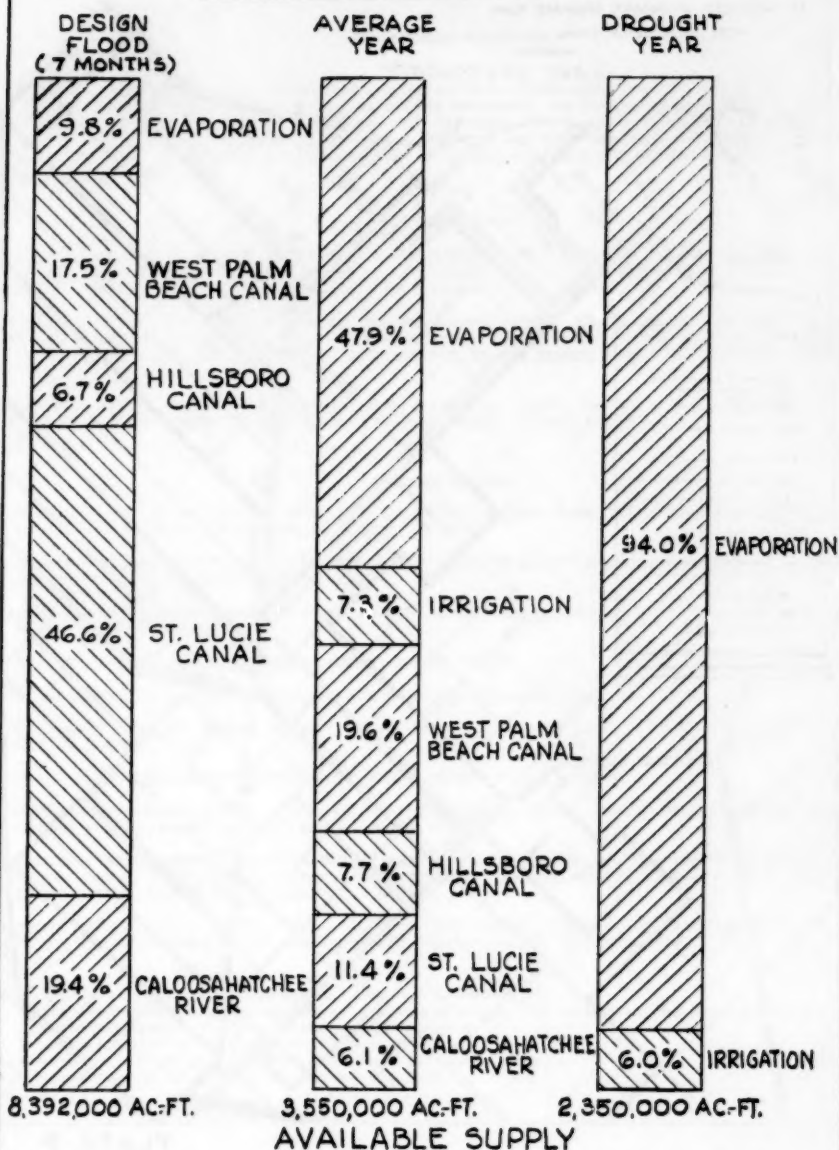
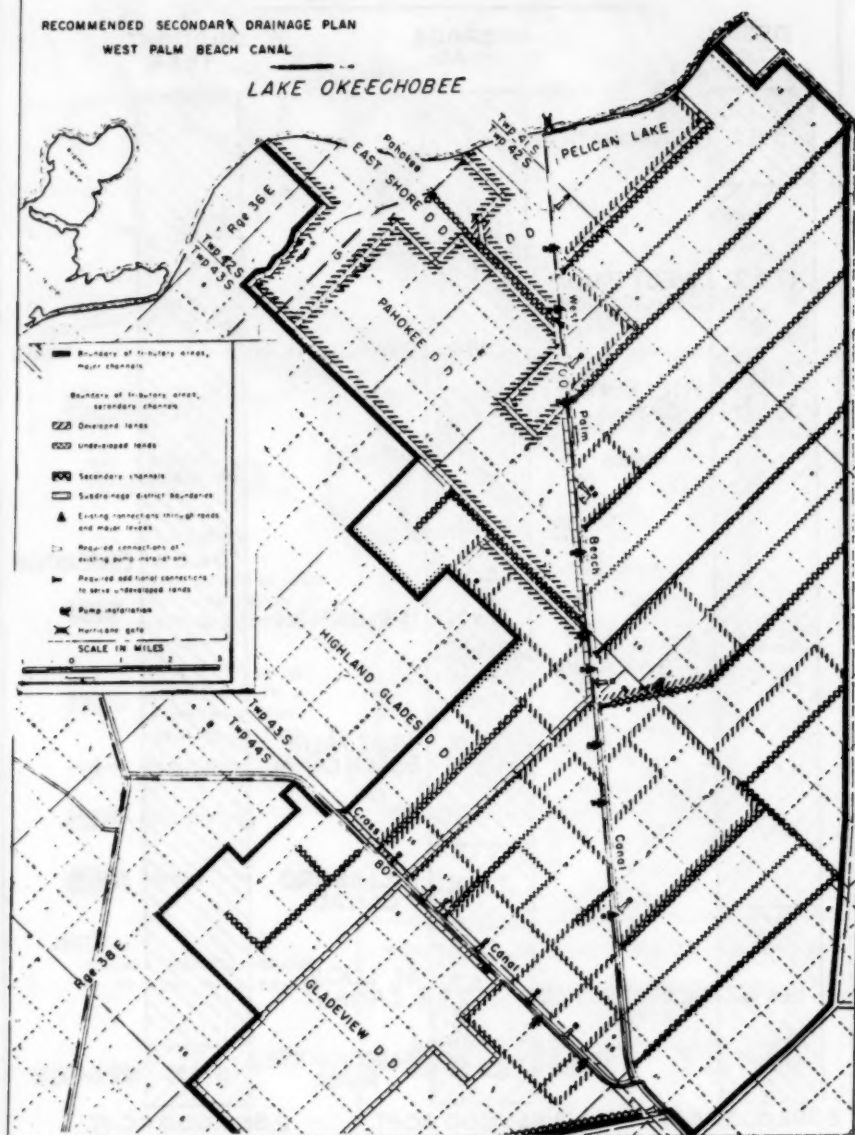


PLATE 8

RECOMMENDED SECONDARY DRAINAGE PLAN  
WEST PALM BEACH CANAL

LAKE OKEECHOBEE



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### VOLUME 79 (1953)

OCTOBER:<sup>b</sup> 290(all Divs), 291(ST)<sup>a</sup>, 292(EM)<sup>a</sup>, 293(ST)<sup>a</sup>, 294(PO)<sup>a</sup>, 295(HY)<sup>a</sup>, 296(EM)<sup>a</sup>, 297(HY)<sup>a</sup>, 298(ST)<sup>a</sup>, 299(EM)<sup>a</sup>, 300(EM)<sup>a</sup>, 301(SA)<sup>a</sup>, 302(SA)<sup>a</sup>, 303(SA)<sup>a</sup>, 304(CO)<sup>a</sup>, 305(SU)<sup>a</sup>, 306(ST)<sup>a</sup>, 307(SA)<sup>a</sup>, 308(PO)<sup>a</sup>, 309(SA)<sup>a</sup>, 310(SA)<sup>a</sup>, 311(SM)<sup>a</sup>, 312(SA)<sup>a</sup>, 313(ST)<sup>a</sup>, 314(SA)<sup>a</sup>, 315(SM)<sup>a</sup>, 316(AT), 317(AT), 318(WW), 319(IR), 320(HW).

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DECEMBER: 359(AT), 360(SM), 361(HY), 362(HY), 363(SM), 364(HY), 365(HY), 366(HY), 367(SU)<sup>c</sup>, 368(WW)<sup>c</sup>, 369(IR), 370(AT)<sup>c</sup>, 371(SM)<sup>c</sup>, 372(CO)<sup>c</sup>, 373(ST)<sup>c</sup>, 374(EM)<sup>c</sup>, 375(EM), 376(EM), 377(SA)<sup>c</sup>, 378(PO)<sup>c</sup>.

### VOLUME 80 (1954)

JANUARY: 379(SM)<sup>c</sup>, 380(HY), 381(HY), 382(HY), 383(HY), 384(HY)<sup>c</sup>, 385(SM), 386(SM), 387(EM), 388(SA), 389(SU)<sup>c</sup>, 390(HY), 391(IR)<sup>c</sup>, 392(SA), 393(SU), 394(AT), 395(SA)<sup>c</sup>, 396(EM)<sup>c</sup>, 397(ST)<sup>c</sup>.

FEBRUARY: 398(IR)<sup>d</sup>, 399(SA)<sup>d</sup>, 400(CO)<sup>d</sup>, 401(SM)<sup>c</sup>, 402(AT)<sup>d</sup>, 403(AT)<sup>d</sup>, 404(IR)<sup>d</sup>, 405(PO)<sup>d</sup>, 406(AT)<sup>d</sup>, 407(SU)<sup>d</sup>, 408(SU)<sup>d</sup>, 409(WW)<sup>d</sup>, 410(AT)<sup>d</sup>, 411(SA)<sup>d</sup>, 412(PO)<sup>d</sup>, 413(HY)<sup>d</sup>.

MARCH: 414(WW)<sup>d</sup>, 415(SU)<sup>d</sup>, 416(SM)<sup>d</sup>, 417(SM)<sup>d</sup>, 418(AT)<sup>d</sup>, 419(SA)<sup>d</sup>, 420(SA)<sup>d</sup>, 421(AT)<sup>d</sup>, 422(SA)<sup>d</sup>, 423(CP)<sup>d</sup>, 424(AT)<sup>d</sup>, 425(SM)<sup>d</sup>, 426(IR)<sup>d</sup>, 427(WW)<sup>d</sup>.

APRIL: 428(HY)<sup>c</sup>, 429(EM)<sup>c</sup>, 430(ST), 431(HY), 432(HY), 433(HY), 434(ST).

MAY: 435(SM), 436(CP)<sup>c</sup>, 437(HY)<sup>c</sup>, 438(HY), 439(HY), 440(ST), 441(ST), 442(SA), 443(SA).

JUNE: 444(SM)<sup>e</sup>, 445(SM)<sup>e</sup>, 446(ST)<sup>e</sup>, 447(ST)<sup>e</sup>, 448(ST)<sup>e</sup>, 449(ST)<sup>e</sup>, 450(ST)<sup>e</sup>, 451(ST)<sup>e</sup>, 452(SA)<sup>e</sup>, 453(SA)<sup>e</sup>, 454(SA)<sup>e</sup>, 455(SA)<sup>e</sup>, 456(SM)<sup>e</sup>.

JULY: 457(AT), 458(AT), 459(AT)<sup>c</sup>, 460(IR), 461(IR), 462(IR), 463(IR)<sup>c</sup>, 464(PO), 465(PO)<sup>c</sup>.

AUGUST: 466(HY), 467(HY), 468(ST), 469(ST), 470(ST), 471(SA), 472(SA), 473(SA), 474(SA), 475(SM), 476(SM), 477(SM), 478(SM)<sup>c</sup>, 479(HY)<sup>c</sup>, 480(ST)<sup>c</sup>, 481(SA)<sup>c</sup>, 482(HY), 483(HY).

SEPTEMBER: 484(ST), 485(ST), 486(ST), 487(CP)<sup>c</sup>, 488(ST)<sup>c</sup>, 489(HY), 490(HY), 491(HY)<sup>c</sup>, 492(SA), 493(SA), 494(SA), 495(SA), 496(SA), 497(SA), 498(SA), 499(HW), 500(HW), 501(HW)<sup>c</sup>, 502(WW), 503(WW), 504(WW)<sup>c</sup>, 505(CO), 506(CO)<sup>c</sup>, 507(CP), 508(CP), 509(CP), 510(CP), 511(CP).

OCTOBER: 512(SM), 513(SM), 514(SM), 515(SM), 516(SM), 517(PO), 518(SM)<sup>c</sup>, 519(IR), 520(IR), 521(IR), 522(IR)<sup>c</sup>, 523(AT)<sup>c</sup>, 524(SU), 525(SU)<sup>c</sup>, 526(EM), 527(EM), 528(EM), 529(EM), 530(EM)<sup>c</sup>, 531(EM), 532(EM)<sup>c</sup>, 533(PO).

a. Presented at the New York (N.Y.) Convention of the Society in October, 1953.

b. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.

c. Discussion of several papers, grouped by Divisions.

d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.

e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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